BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Experiment Pointing Requirements for AAP 1-2 and AAP 3a Missions Case 610

DATE: April 10, 1969

FROM: T. C. Tweedie, Jr.

ABSTRACT

The experiments assigned to AAP 1-2 and AAP 3a were reviewed to determine their pointing requirements and the feasibility of performing them on the OA without the addition of special pointing devices. The experiment pointing requirements were obtained from existing documentation, and conversations with the Principal Investigators. Of the nine experiments examined, six have nominal pointing requirements and can easily be accommodated by the OA. The three experiments with more stringent requirements can also be accommodated without the addition of special pointing devices but, to meet their requirements, some considerations in either mission planning or OA control are needed.

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MEMORANDUM FOR FILE

At the request of NASA Headquarters/ML, a short review of the experiments assigned to AAP 1-2 and AAP 3a missions was made to determine their pointing requirements and the feasibility of performing them on the OA without the addition of special pointing devices. The experiments considered were from the 4B option approved by the MSFEB, and assigned to AAP. This memo describes the experiment pointing requirements as interpreted from existing documentation and conversations with the experiment Principal Investigators. In a companion memo,* the form of the maneuvers by the OA and the amount of fuel used in performing the experiments is detailed.

The experiments reviewed for pointing requirements were:

S009 Nuclear Emulsions
S018 Micrometeorite Collection
S019 UV Stellar Astronomy
S020 X-Ray/UV Solar Photography
S063 UV Airglow Horizon Photography
S073 Gegenschein/Zodiacal Light
S101 Multispectral Terrain Photography
T025 Coronagraph Contamination Measurements
T027 Contamination Measurements

A description of the pointing requirement for each experiment is given in Appendix A.

It was found that the pointing requirements stated in the existing documentation in many cases were out of date or did not accurately represent the desire of the P. I. In

*Memorandum for File, "Compatibility of the 4B Experiment List with Pointing and Propellant Capabilities of the WACS," by J. J. Fearnsides, April 10, 1969.

several instances, the requirements stated did not fully describe the desired mode of operation or completely explain options that might be considered in meeting the objectives of the experiments. In other cases, experiments were found to have several parts with the requirements of one part severely limiting the operational feasibility of the whole experiment.

Summary

Seven of the experiments (except S009 and S101) require the use of the scientific airlock. Of these seven, three (T027, S063, and S073) use essentially the same equipment, a camera and photoelectric photometer, mounted to a boom extended from the scientific airlock of the spacecraft. The built-in flexibility of the boom minimizes the attitude control capability that the OA must provide although initial course target acquisition and hold must be provided. An improved version of S018 (S149) will also use the boom but not during the manned portion of the mission. S149 collects primary data during the unmanned storage between the AAP 1-2 and 3a mission and between the 3a and 3-4 mission.

Three of the experiments (S020, T025, and T027) are solar oriented. Since the angle between the orbital plane and the earth-sun line, β angle, depends on the date and time of launch and the time into the mission, some out-of-plane pointing of the OA may be required to perform these experiments. The selection of suitable star fields for S019 must wait until the orbital parameters of the OA are better defined but there does not appear to be any difficulty in choosing an adequate number.

The following short statements of the pointing requirements of each experiment are extracted from the more detailed discussion in Appendix A.

S009 - Operation of S009 during the unmanned storage of the OA between AAP 1-2 and 3a and AAP 3a and 3-4 does not impose a pointing requirement on the OA.

S018 - The improved version of the S018 experiment (S149) collects data between AAP 1-2 and 3a and AAP 3a and 3-4. S149 is attached to a boom extended through the scientific airlock. In this mode no active spacecraft pointing is required.

S101 - The photographs of the earth are taken through a window of the spacecraft. Only limited maneuvering of the spacecraft is required to orient a window for the photographic sequences.

T027 - The photometric portion of T027 requires only that a deadband of ± 1/2° be held during data gathering. The movable mount at the end of the boom can accommodate β angles up to 40° before requiring extensive spacecraft positioning. The sample exposure portion of T027 does not require pointing control.

S063 - If S063 uses equipment attached to the movable mount of the T027 boom then the pointing requirements are similar to those of experiment T027. If S063 uses only the hand-held Hasselblad camera, then S063 has only minor pointing requirements.

S073 - S073 uses the T027 boom and movable mount. The pointing requirements are similar to those of T027.

T025 - As long as the sun is occulted, useful photographs of the contamination will be obtained. Since the T025 coronagraph is designed to over occult the sun, the burden of the spacecraft holding a fixed attitude is lessened. The spacecraft must move an amount equal to the solar β angle to acquire the sun, and must hold within ± 1/2°.

S019 - With sufficient flexibility in choosing the star fields for the observing program and with the low roll rates required to produce the spectral lines, the pointing requirements appear realizable with minimum fuel expenditure.

S020 - The pointing requirements for S020 call for moving the spacecraft an amount equal to the solar β angle to acquire the sun and holding to within ± 1/4° during an exposure. This accuracy can be accomplished by manual control of the OA.

Of the nine experiments examined, six have nominal pointing requirements and can easily be accommodated by the OA. The three experiments with more stringent requirements (T025, S019, and S020) can also be accommodated without the

addition of special pointing devices but, to meet their requirements, some considerations in either mission planning or OA control are needed.

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Attachment
Appendix A

APPENDIX A

S009 Nuclear Emulsion

The purpose of S009 is to investigate the component of the heavy primary nuclei present in galactic cosmic radiation by using nuclear emulsions.

During the manned portion of the AAP-1/AAP-2 mission, experiment S009 is stored in a passive non-data gathering mode. Just prior to crew return after 28 days in orbit, the experiment is activated. During the unmanned orbital storage between AAP-1/AAP-2 and AAP 3a the experiment collects data. During data gathering the experiment must be pointed such that its field of view does not intercept the spacecraft, the earth, or its atmosphere. An experiment mounting location in the MDA has been identified such that with the OA in a gravity gradient storage mode the field of view does not intercept the earth. After the 3a rendezvous, S009 is covered with a protective shield and stored for return in the CM at the end of the 3a mission. This sequence is again repeated during the storage between 3a and AAP-3/AAP-4.

The experiment, therefore, does not create an additional pointing requirement.

S018 Micrometeorite Collection

S018 exposes polished surface to the external spacecraft environment to detect meteorites through impacts on the exposed panels. Extended through the scientific airlock, the most favorable orientation of this experiment is with the collecting panels' area in the direction of the velocity vector. Some reports indicate that the orientations should be within ± 30° of the velocity vector. This is a guideline rather than a firm requirement. The only orientation that should be avoided is with the exposed panels facing the earth.

Eight hours of exposure time is desired. During this time, thruster firing should be minimized. Thrusters which would have a plume impact on the panels should not be fired during data gathering periods.

It should be noted that an improved version of this experiment, S149, is now being considered. In its principle mode it is extended through the scientific airlock on the T027 boom just prior to crew departure at the end of the AAP 1-2 mission. The experiment will be activated on command from the ground. The panels of S149 will be exposed and collect impact data during the unmanned storage period of the OA between mission AAP 1-2 and AAP 3a. Oriented on the end of the T027 boom, S149 does not require active spacecraft pointing.

S019 UV Stellar Astronomy

The purpose of S019 is to obtain a large number of moderate and low dispersion stellar spectra of sufficient resolution to permit study of UV line spectra and energy distribution of early type stars. S019 records the ultraviolet spectrum of selected star fields on film using a 4° field of view slitless prism spectrometer installed in the scientific airlock. Since images of the stars will appear as points on the film, controlled motion normal to the dispersion plane during a film exposure is necessary to produce spectral lines and bands from these point images. The prism in the spectrometer may be installed in such a way that the direction of the required controlled rotation is about the spacecraft axis of minimum inertia. The P. I. estimates that the controlled rate should be between 0.0028°/sec. and 0.011°/sec. The rates in the two other axis should be less than the controlled rate during an exposure time which may vary from 30 sec. to 120 sec. The optic axis of the spectrometer should be held within $\pm$ 2° of the center of the star field during observation. A 7° field of view guiding telescope with cross hairs aligned to the spectrometer is provided for target observation, acquisition, and hold. This experiment is performed during the night portion of an estimated 10 to 15 orbits.

The observing program proposed consists of obtaining 5 photographs of each of 27 separate star fields. While the

star fields have not been selected pending determination of the spacecraft orbital inclination, altitude, date and time of launch, they will probably lie in or near the galactic plane.

Selection of interesting star fields, however, does not appear to be a problem. Dr. Karl Henize, the P. I. of S019 has stated,* "...I foresee no difficulty in finding an adequate number of interesting star fields to occupy the assigned time. As the orbit passes particularly interesting star fields, we would hope that some priority might be given to scheduling this experiment. I realize that many time conflicts will prevent us from observing whenever we choose but it would be possible, once the launch time and date are specified, for us to reprint a list of, say, 60 desirable fields of which 20 to 30 might fit comfortably in the flight plan."

With this kind of flexibility in choosing star fields and the very low roll rates required to produce the spectral lines, this experiment appears to have nominal pointing requirements.

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*"Compatibility of Experiment S019 with the Proposed Attitude Control of the AAP Cluster," Karl G. Henize, July 11, 1968.

S020 X-Ray/UV Solar Photography

Using a diffraction grating spectrometer, experiment S020 obtains X-ray and ultraviolet spectral information about the sun. The optic axis of the slit of the spectrometer, when installed in the scientific airlock, must be pointed to the center of the sun and maintained to ± 0.25° during an exposure. The longest exposure desired is 60 minutes which may be divided into two portions and accomplished on successive orbits. Other exposure times are 5, 8, 15 and 30 minutes. Spacecraft rates are not important.

The sun is acquired through the use of a telescope with a course ± 7° field of view and a fine ± 1-3/4° field of view. On the fine field of view display, a grid permits positioning the solar image to within ± 1/4°. The field of view of the spectrometer slit is 1/2° by greater than 1-1/2°. Since the spectrometer slit is rectangular, the pointing control is more critical in the short dimension (perpendicular to the slit) than in the long dimension (parallel to the slit).

The pointing requirements for S020 call for moving the spacecraft or the experiment an amount equal to the existing β angle, to acquiring the sun, and holding to within ± 1/4° during an exposure. This accuracy can be accomplished by manual control of the OA.

S063 UV Airglow Horizon Photography

Experiment S063 is divided into three parts: nighttime airglow observations, daytime airglow observations performed near the terminator, and direct daytime airglow observations. S063 is designed to use the T027 boom, camera, and photometer with a change in the photometer filters planned for the visible and UV nighttime airglow observations. The direct daytime airglow is photographed from inside the spacecraft using a hand-held Hasselblad camera. For this part of the experiment, the photometer and camera mounted on the T027 boom scan back and forth across the sky, airglow and horizon. This cycle is repeated in different directions by moving the T027 platform. Spacecraft attitude hold of $\pm$ 1/2° is adequate.

One revolution is needed for the terminator airglow observations (crossing the terminator twice). The boom orientation is the same as in the nighttime observations.

Direct daytime observations are made by photography from inside the OA through a spacecraft window. One daytime revolution with the window $\pm$ 10° to the nadir at local noon and spacecraft rates less than 0.01/sec., although not stated, seem sufficient to accomplish the daytime photography. Exposure times will be on the order of 30-60 seconds.

New information indicates that the T027 camera/ photometer system cannot accomplish the nighttime and terminator portions of S063 and that only the direct photography with the Hasselblad will be attempted. Thus, S063 has only minor pointing requirements.

S073 Gegenschein/Zodiacal Light

Experiment S073 has a new Experiment Implementation Plan and a new Principal Investigator. The purpose of S073 is to measure the brightness and polarization of the night sky particularly in the ecliptic plane. In addition, the extent and nature of the daytime spacecraft corona due to a contaminants near the spacecraft will be determined. The new experiment proposal was formulated to use the T027 extension boom and similar detection equipment. In S073, a photometer and camera are mounted to the T027 platform and extended through the scientific airlock. Using the elevation and azimuth mechanism of the platform, a scan of a portion of the celestial sphere is made during the nighttime of three orbital revolutions. It is desired to observe the gegenschein and zodiacal light in the ecliptic plane.

On the three nighttime passes, the experiment is directed towards the ecliptic plane; on the one daytime pass the experiment is directed towards the sun with a scan about this direction attempting to determine the brightness of the spacecraft corona. A spacecraft attitude hold of $\pm$ 1/2° is sufficient for S073.

This implementation of S073 does not pose additional spacecraft pointing requirements.

S101 Multispectral Terrain Photograph

Experiment S101 consists of six ganged Hasselblad cameras operating in selected spectral bands simultaneously photographing selected land masses in the United States and possibly Australia. The cameras mounted at a window are pointed from inside the spacecraft to within ± 10° of the nadir (± 2° is desired) during photo taking. The exposure times are in the range of about 1/25-1/250 seconds. The rate of motion of the cameras during an exposure should be less than 5°/min. relative to the target. During photography, the cloud cover should be less than 30% and the target-sun lighting angle greater than about 15°. The P. I. estimates that in 15 passes over the U. S. approximately 37 targets can be photographed.

T025 Coronagraph Contamination Measurements

The purposes of T025 are to investigate the amount, size and velocity of particulate contamination near the spacecraft and, if possible, to measure the brightness of the solar F corona.

The T025 coronagraph is pointed at the sun through the airlock during data gathering periods. Referenced to the sun, the Principal Investigator desires an attitude pointing deadband of ± 1/2°. Since the occulting discs of the coronagraph subtend about a 3° field of view, the sun (1/2° angular diameter) is overocculted. The attitude rate is not important if the sun remains occulted during a single exposure period; however, a nominal rate of 0.012°/sec. is quoted.

Exposures from about 1/240 sec. up to 1 minute are planned. The shorter exposures (less than one second) are associated with the contamination portion of this experiment; the longer exposures (order of one minute) are needed for the F corona investigations. Approximately 75% - 80% of the available film is used for the contamination photos. The experiment is operated on the sun side of 4 orbits. It is desired that these orbits be non-consecutive if possible, to obtain a diversity of environmental conditions. The experiment should be scheduled in the middle or towards the end of the

mission to eliminate the effects of early spacecraft outgassing and also scheduled when the solar β angle is small.

The contamination photos are taken in sequences of about five exposures (from 1/240 sec. to 1/10 sec.) at a particular F/ stop; the F/ stop is then changed and another five exposures taken. This procedure is repeated at about six F/ stops. During an exposure sequence, the RCS thrusters should not be fired; however if required, care should be taken so that the engine plume does not intercept the field of view of the experiment.

The spacecraft or experiment must move an amount equal to the β angle to acquire the sun, and must hold at ± 1/2°.

T027 Contamination Measurements

The sample array exposure portion of experiment T027 has no pointing requirements.

In the photometric portion of T027, a photometer and camera mounted to a platform are extended from the scientific airlock on a boom to measure the sky brightness due to contaminants near the orbiting spacecraft. The platform on which the photometer and camera are mounted has two-axis rotation which permits data taking with only limited constraints on the orientation and pointing of the OA. The WACS attitude deadband of $\pm$ 1/2° is sufficient spacecraft pointing control. The photometer and camera platform and boom must be sun directed; data taking without spacecraft maneuvering is possible through platform orientation if the solar β angle is less than 40°. A spacecraft attitude rate of 0.02°/sec. or less is needed to prevent smearing of the photographs during the longest exposure times (100 seconds). The photometric portion of T027 requires four daylight revolutions.

The experiment requires only the 1/2° deadband hold during the portion of the mission with $\beta < 40°$.